Three-Terminal Suspended Graphene Energy Efficient Switches

Eli Martel
Thomas Szkopek
Electrical Engineering, McGill University, 3480 University Street, Montréal, Canada
eli.martel@mail.mcgill.ca

For the last 70 years, solid-state technology has evolved immensely to reflect our dependence on faster, more dependable and more energy efficient systems. Modern electronic hardware still contributes significantly to our energy consumption. In 2018, approximately 200TWh of electricity was consumed by the servers and storage systems of data centres worldwide, and that figure is expected to rise up to 40,000 by 2030 [1]. The average energy consumed per solid-state transistor per clock-cycle in a circuit is $E \propto CV^2$, where C is the average capacitance dominated by metallic connections and $V \sim 1V$ is the operating voltage [2]. Finding an alternative to conventional transistor technology to reduce the dissipated energy is crucial. Electromechanical switches could reduce the operating voltage, while maintaining high on/off current ratios, thereby reducing energy consumption while retaining competitive operating speeds and relatively small sizes. Our goal is to develop a three-terminal electromechanical switch using a suspended graphene structure that can operate below 1V. Graphene is the strongest known material with a Young's modulus of $Y \sim 1TPa$, however its elastic stiffness $E \propto Yt$ is low compared to other materials due to its atomic thinness $t = 0.34$ nm. Theoretical simulations show that suspended graphene switches can be operated with voltages much lower than 1V by optimizing device geometry [3,4,5]. We can establish optimal designs in order to fabricate devices with operating voltages around 100 mV using state-of-the-art cleanroom equipment, scanning electron microscopy (SEM), electronic transport measurements and actuation tests. We will present our experimental work towards realizing suspended graphene NEMS switches combining large area CVD graphene and simple silicon / silicon oxide processing methods.

REFERENCES

[1] N. Jones, Nature 561 (2018), p. 163-166
[2] A. M. Ionescu and H. Riel, Nature 479 (2011), p. 329
[3] M. AbdelGhany, E. Ledwosinska and T. Szkopek, Appl. Phys. Lett. 101 (2012), p. 153102
[4] M. AbdelGhany and T. Szkopek, Appl. Phys. Lett. 104 (2014), p. 013509
[5] T. Szkopek and E. Martel, Progress in Quantum Electronics (2020, publication pending)

FIGURES

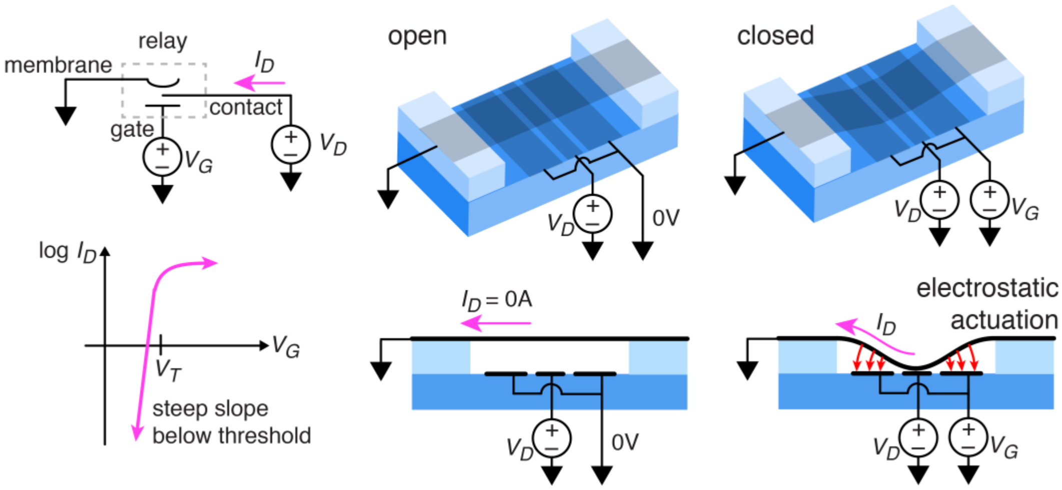

Figure 1: The proposed graphene nanomechanical switch, where the three terminals consist of a suspended graphene membrane, a bottom contact strip, and a split gate. A low-threshold voltage V_T, and steep slope in log I_D versus V_G below threshold can enable low-voltage operation.